Satellite Measurements of Passive Fluorescence and Comparisons with Field Data

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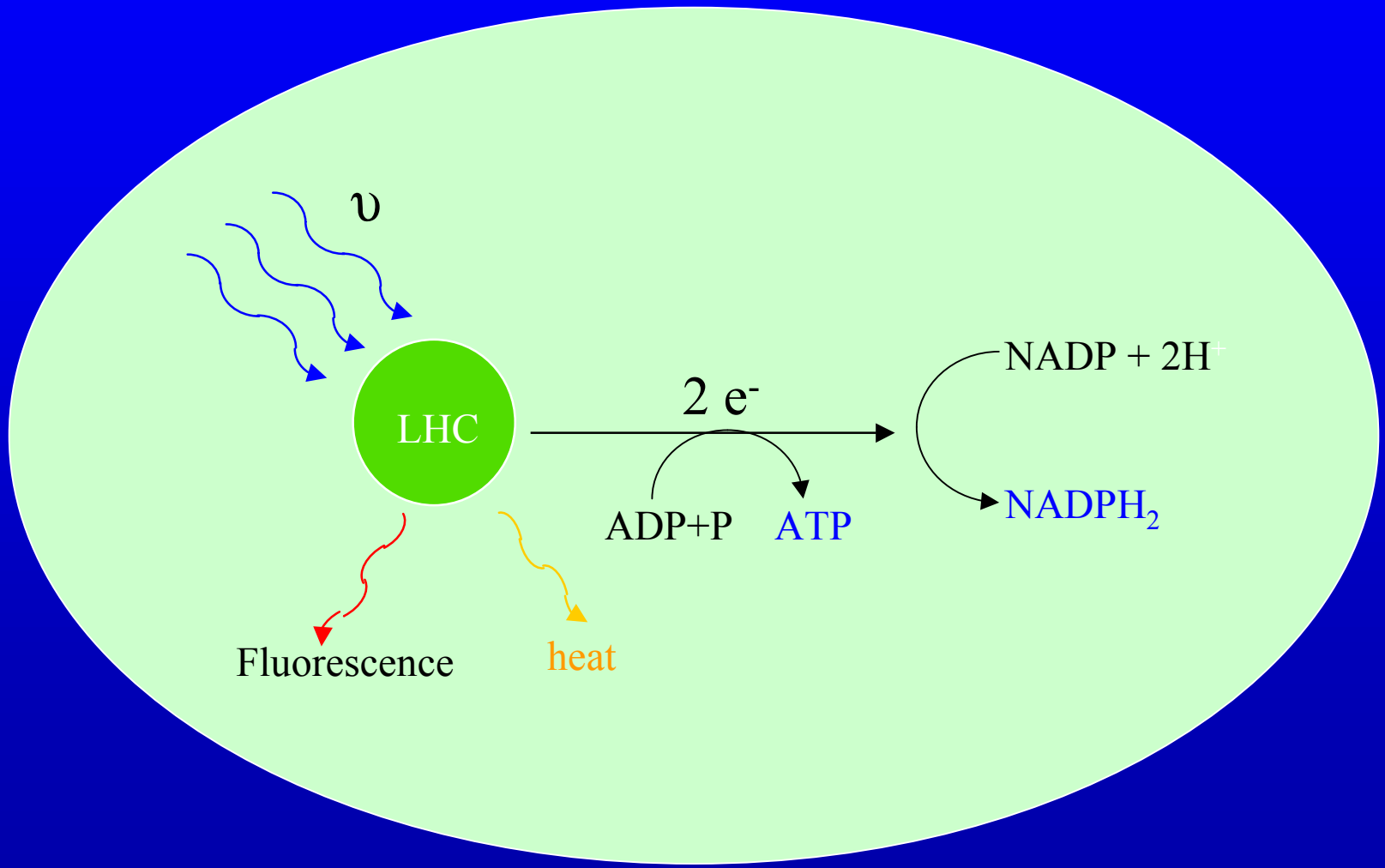
Context

- How do ecosystems respond to and affect global environmental change and the carbon cycle?
- Ocean carbon cycle models need to resolve more processes and structures
  - Changes in ecosystem structure/composition
  - Changes in physical processes
  - Interaction of ecology and physics
- Particular focus on coastal zones as part of GLOBEC project

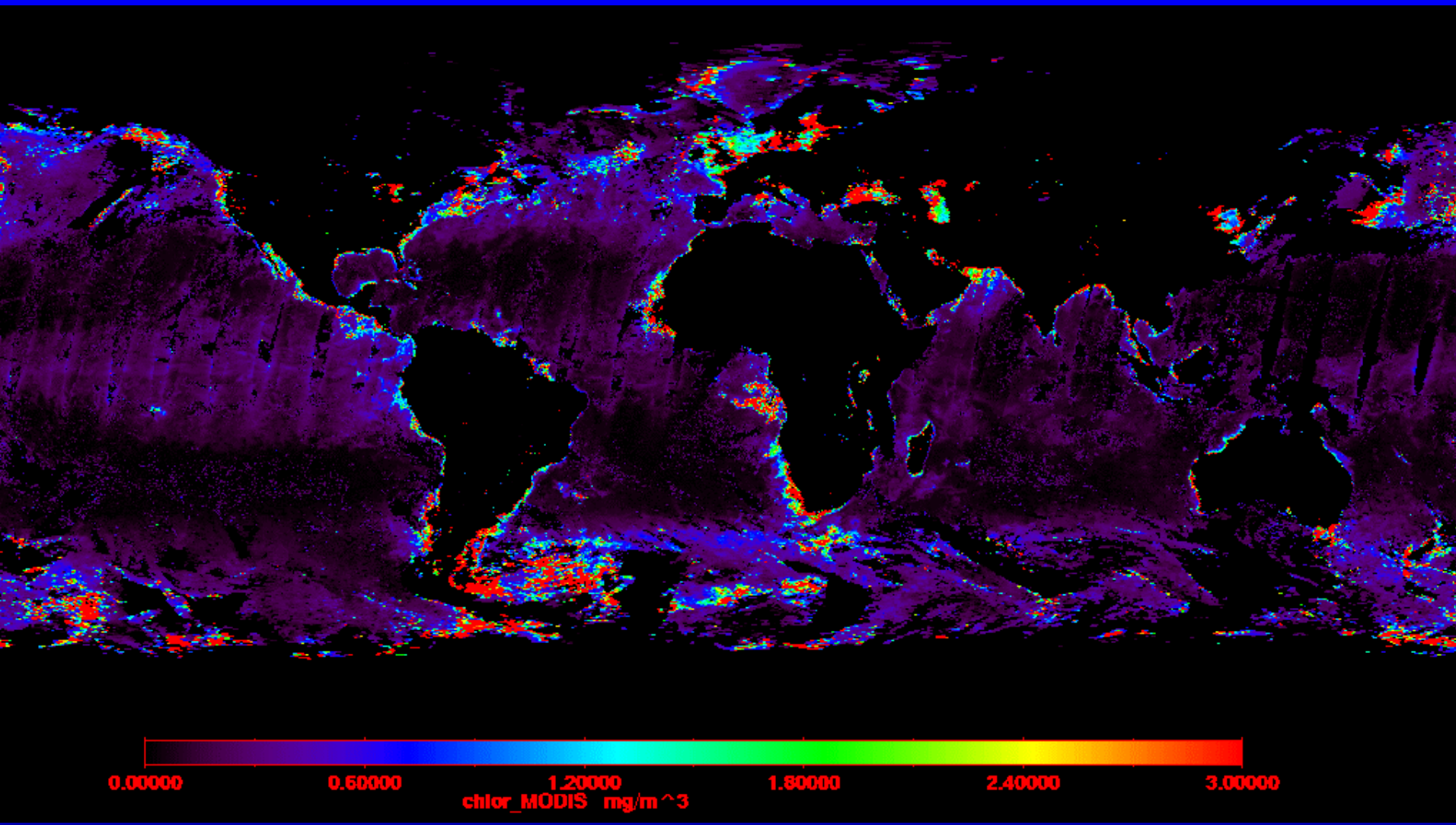
Satellite-based Estimates of Primary Productivity

Study	50°-90° S
Longhurst et al. (1995)	4 Pg C/yr
Behrenfeld and Falkowski (1997) corrected by Arrigo et al.	4.8
Antoine et al. (1996)	5.9
Arrigo et al. (1998)	3.2 - 4.4
Moore and Abbott (in press) - SeaWiFS	2.9

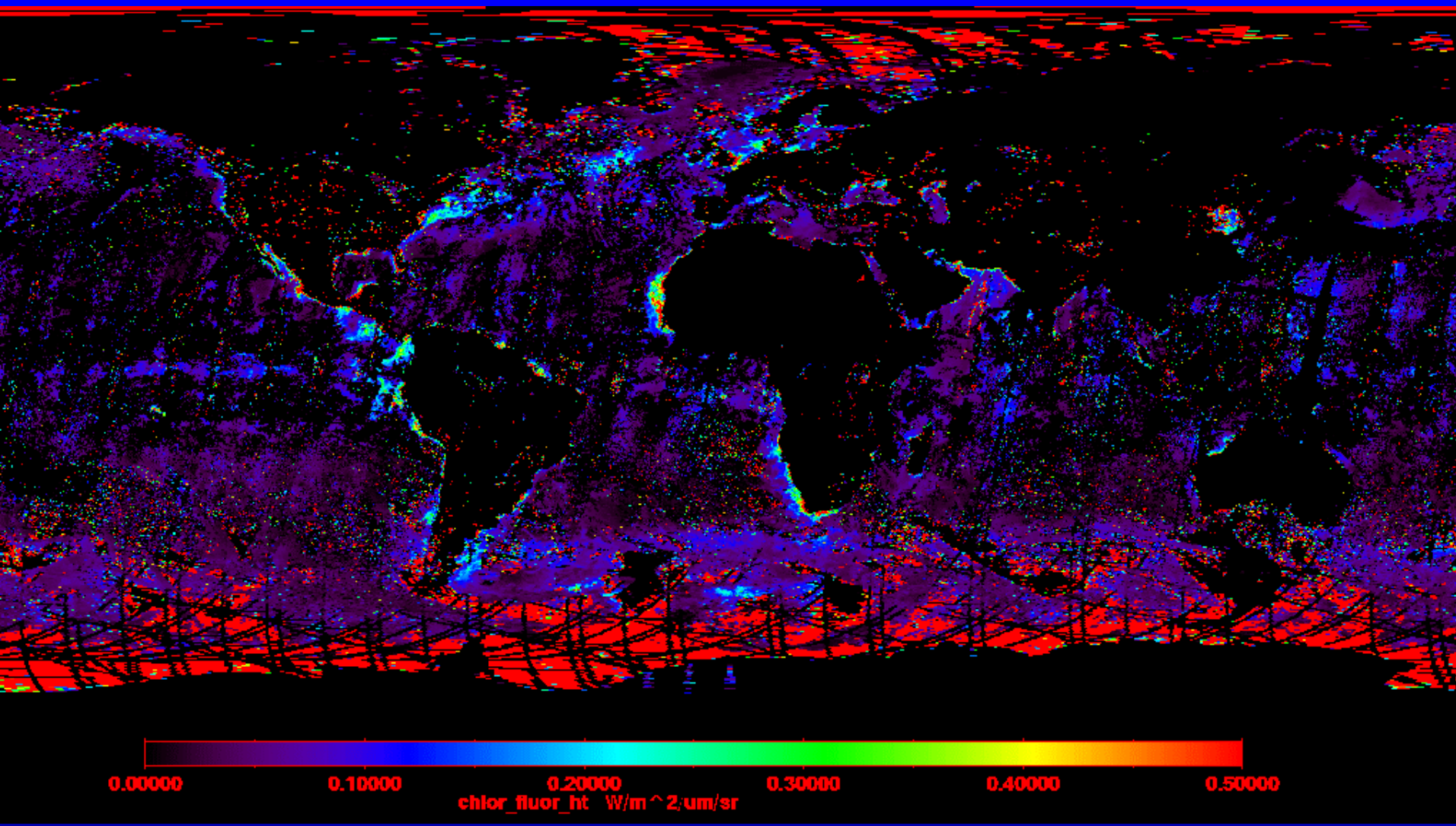
Light Harvesting and Fluorescence



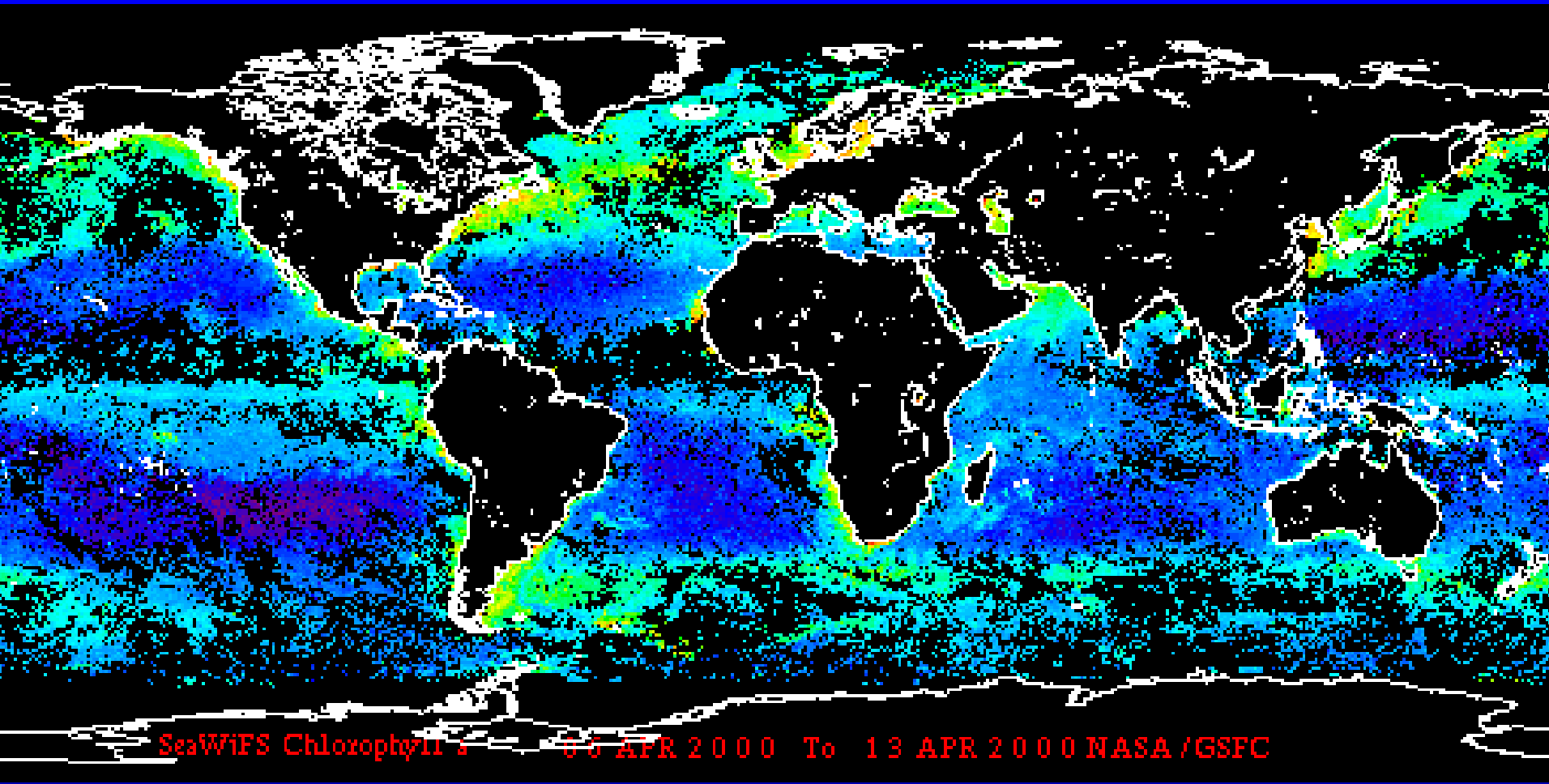
MODIS Chlorophyll, 5-7 April 2000



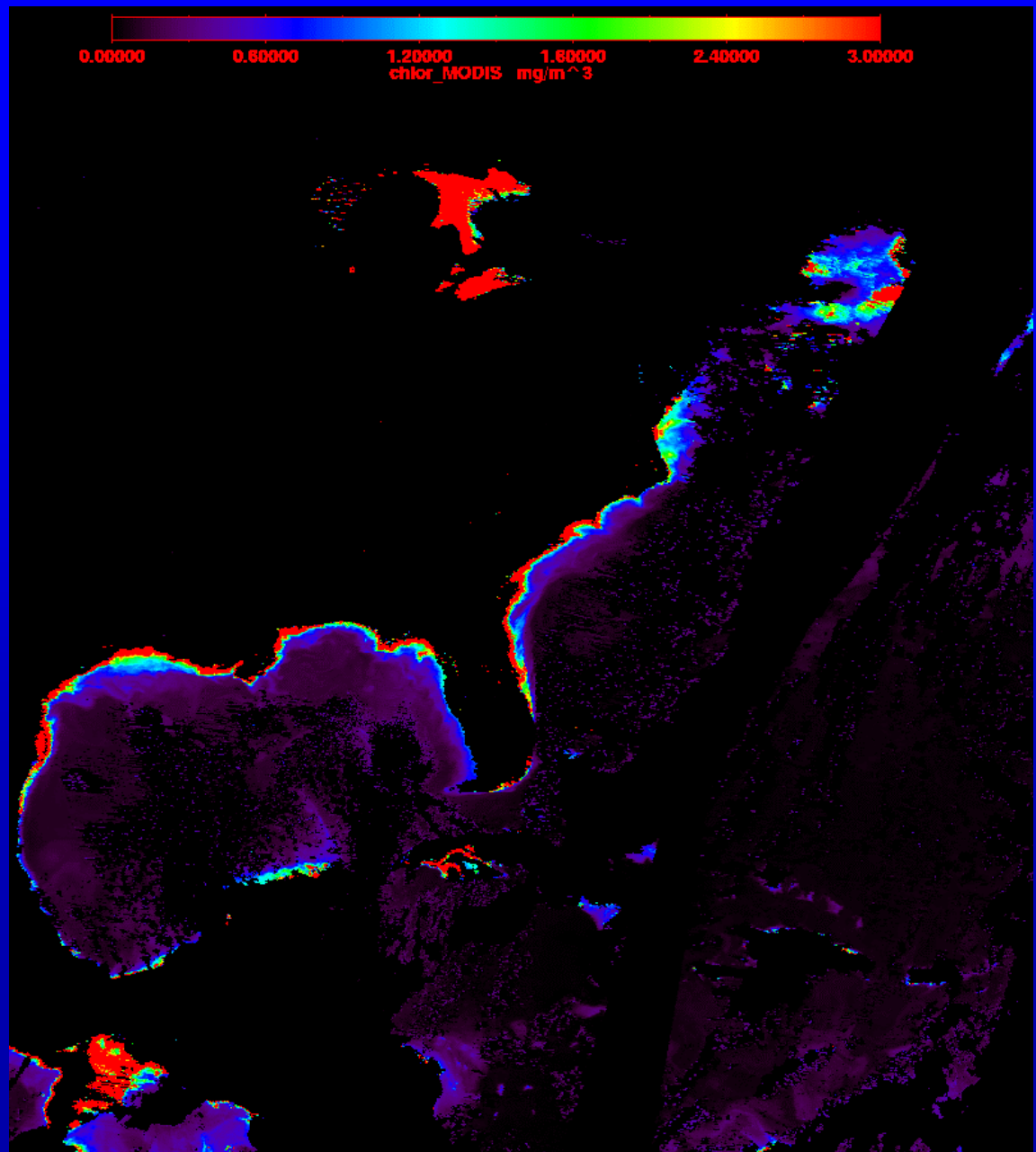
MODIS FLH, 5-7 April 2000



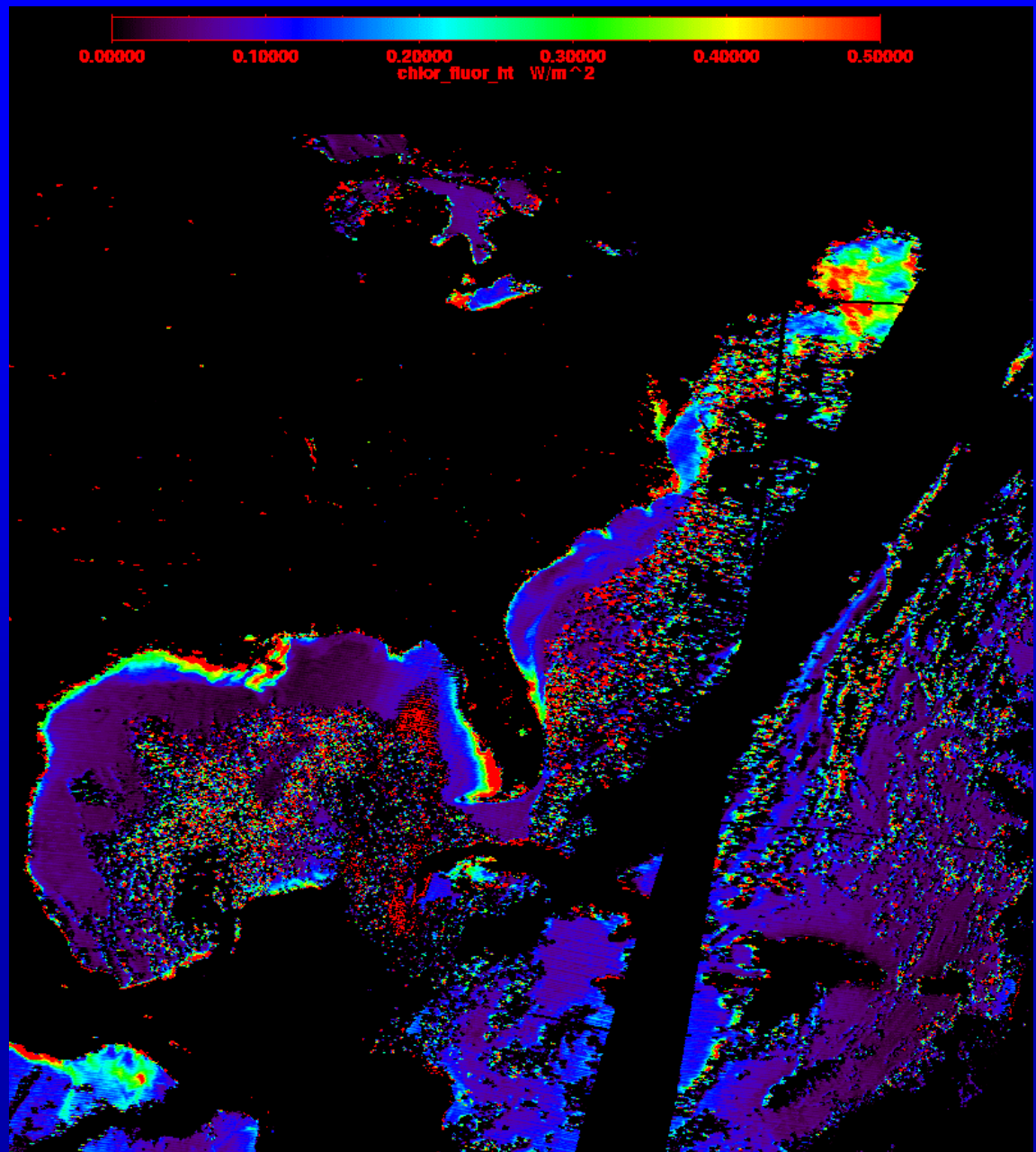
8-Day SeaWiFS (6 April)



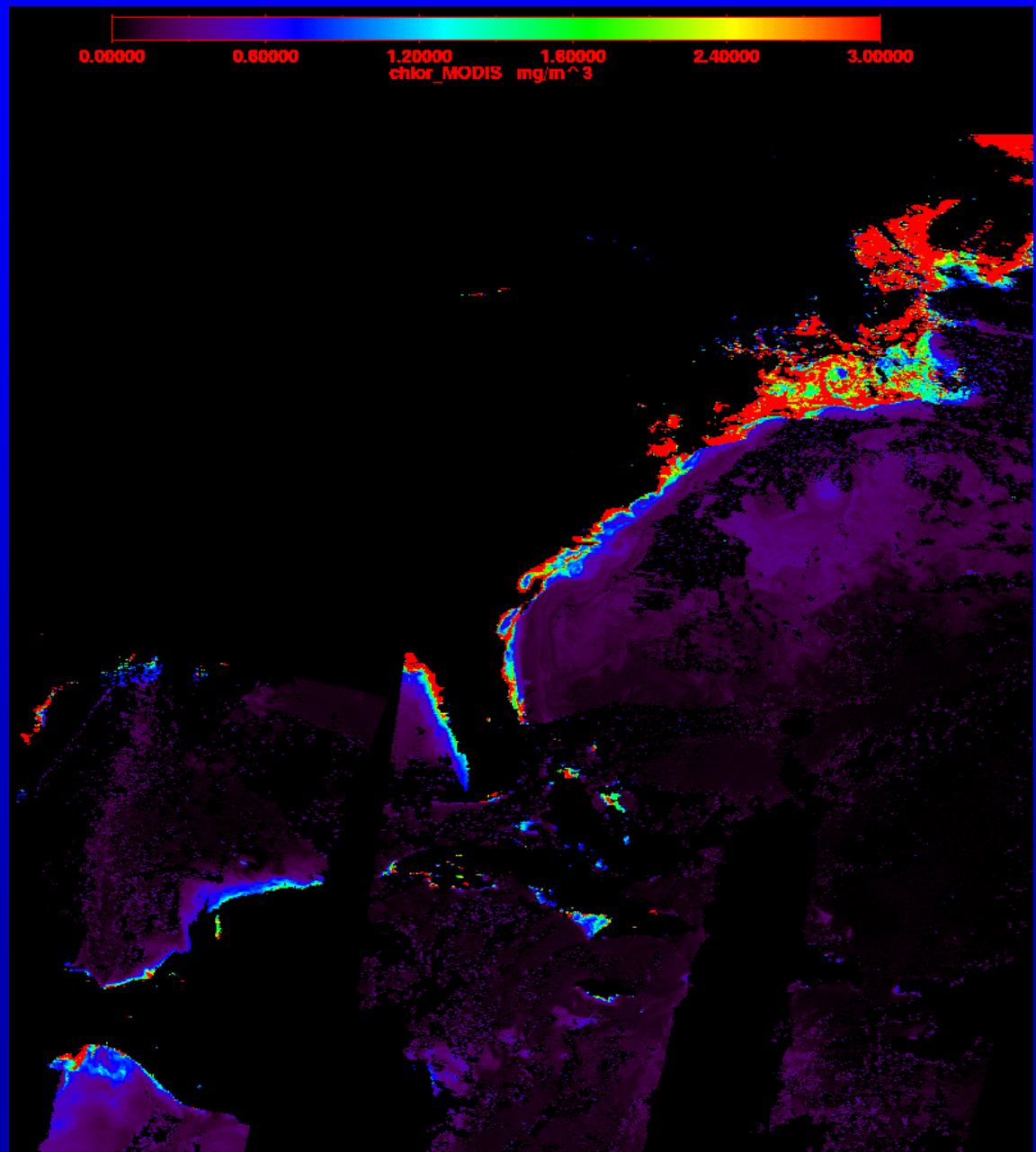
MODIS Chl., Gulf Stream, 5 April



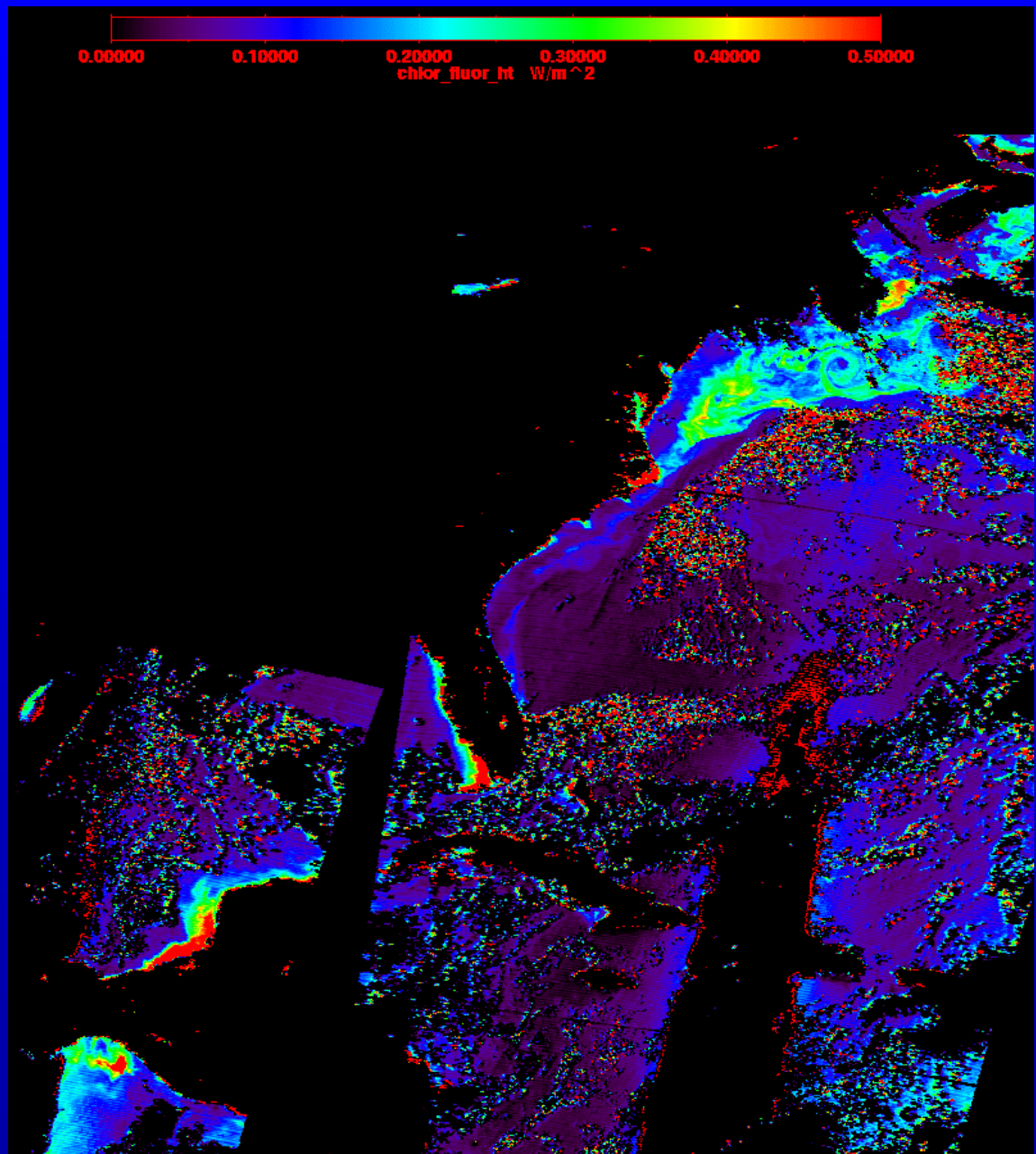
MODIS FLH, Gulf Stream, 5 April



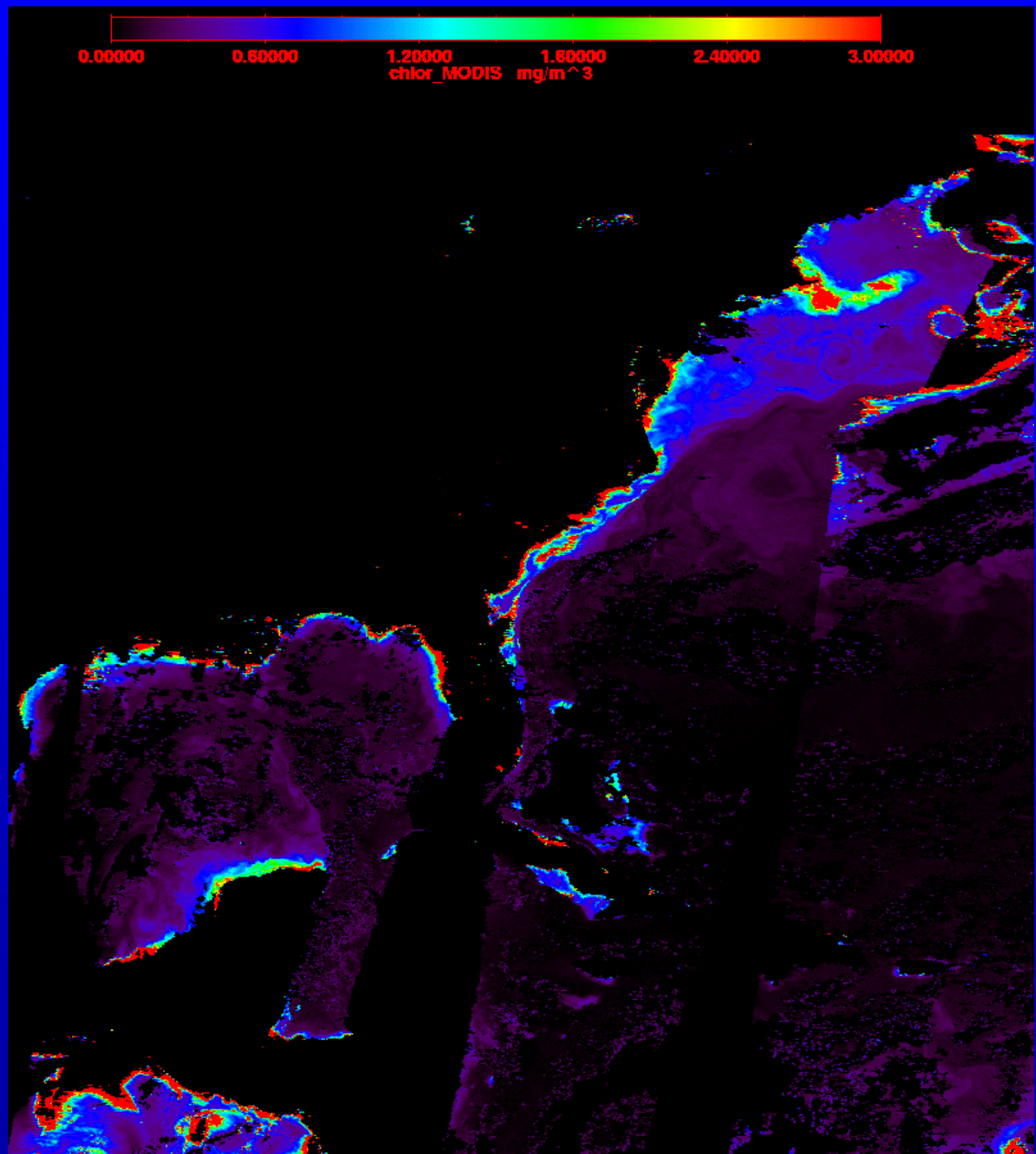
MODIS Chl., Gulf Stream, 6 April



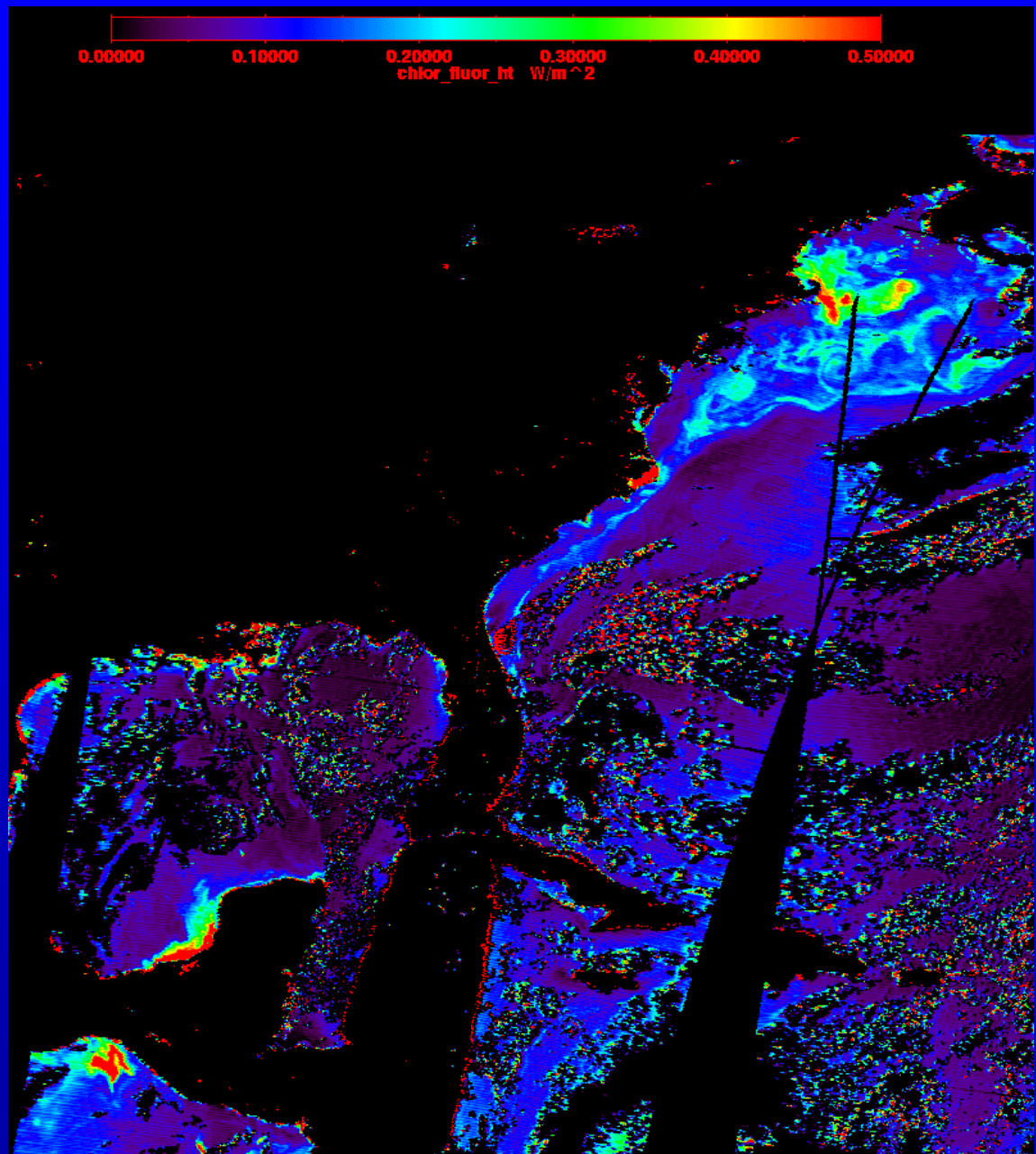
MODIS FLH, Gulf Stream, 6 April



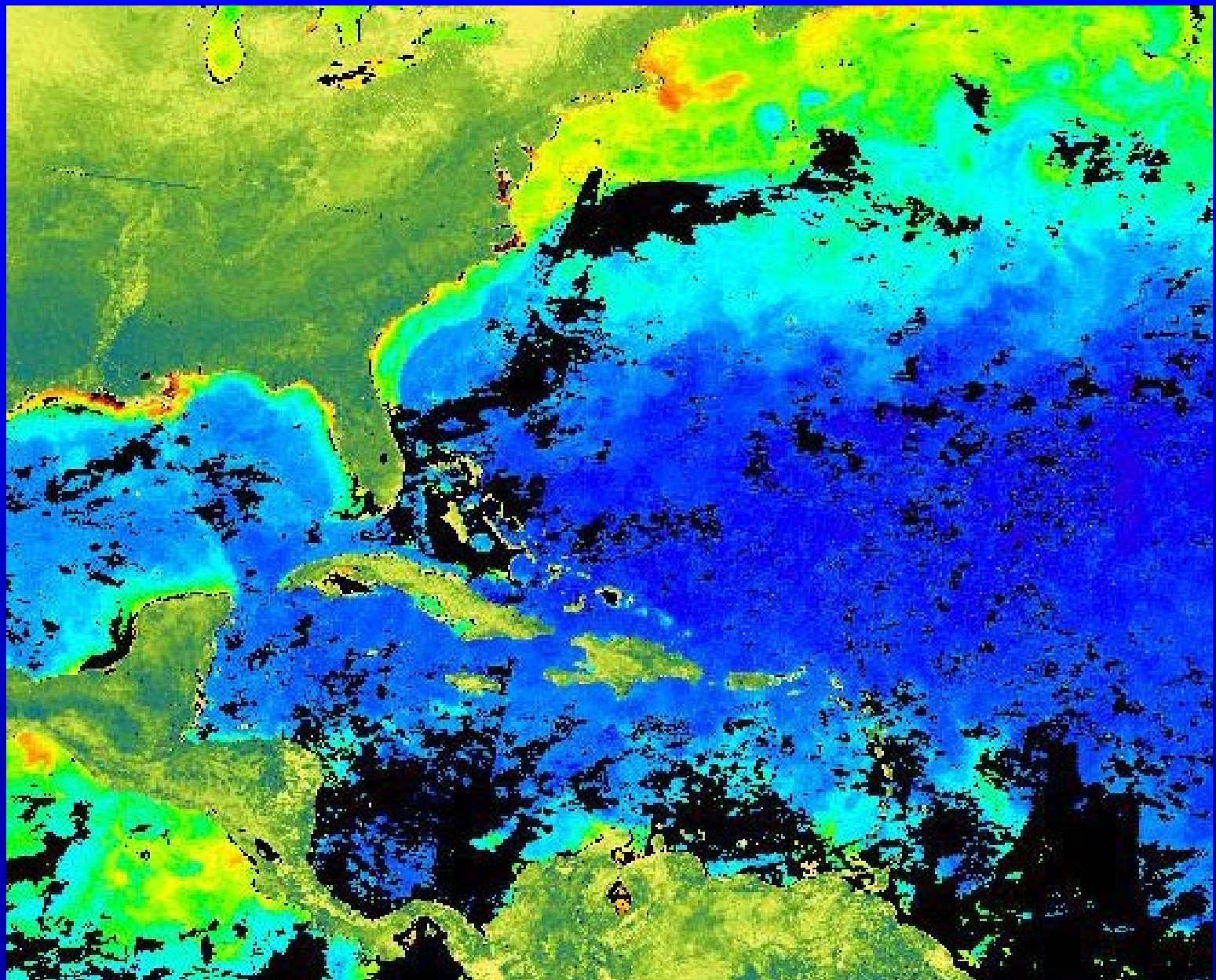
MODIS Chl., Gulf Stream, 7 April



MODIS FLH, Gulf Stream, 7 April



SeaWiFS April 2000



Fluorescence and Productivity

- $F = [chl] \times (PAR \times a^*) \times \Phi_F$

  where F = fluorescence

  [chl] = chlorophyll concentration

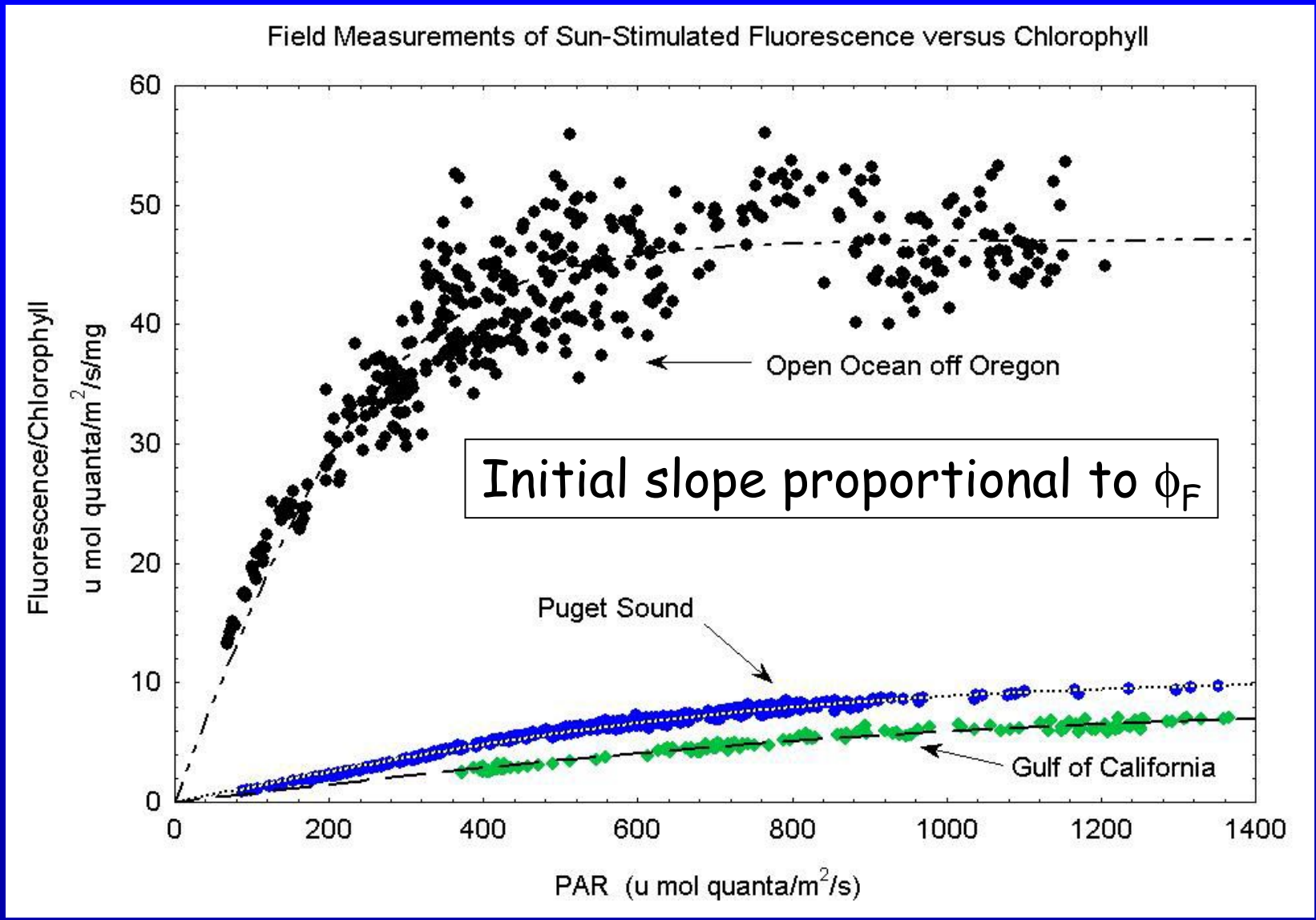
  PAR = photosynthetically available radiation

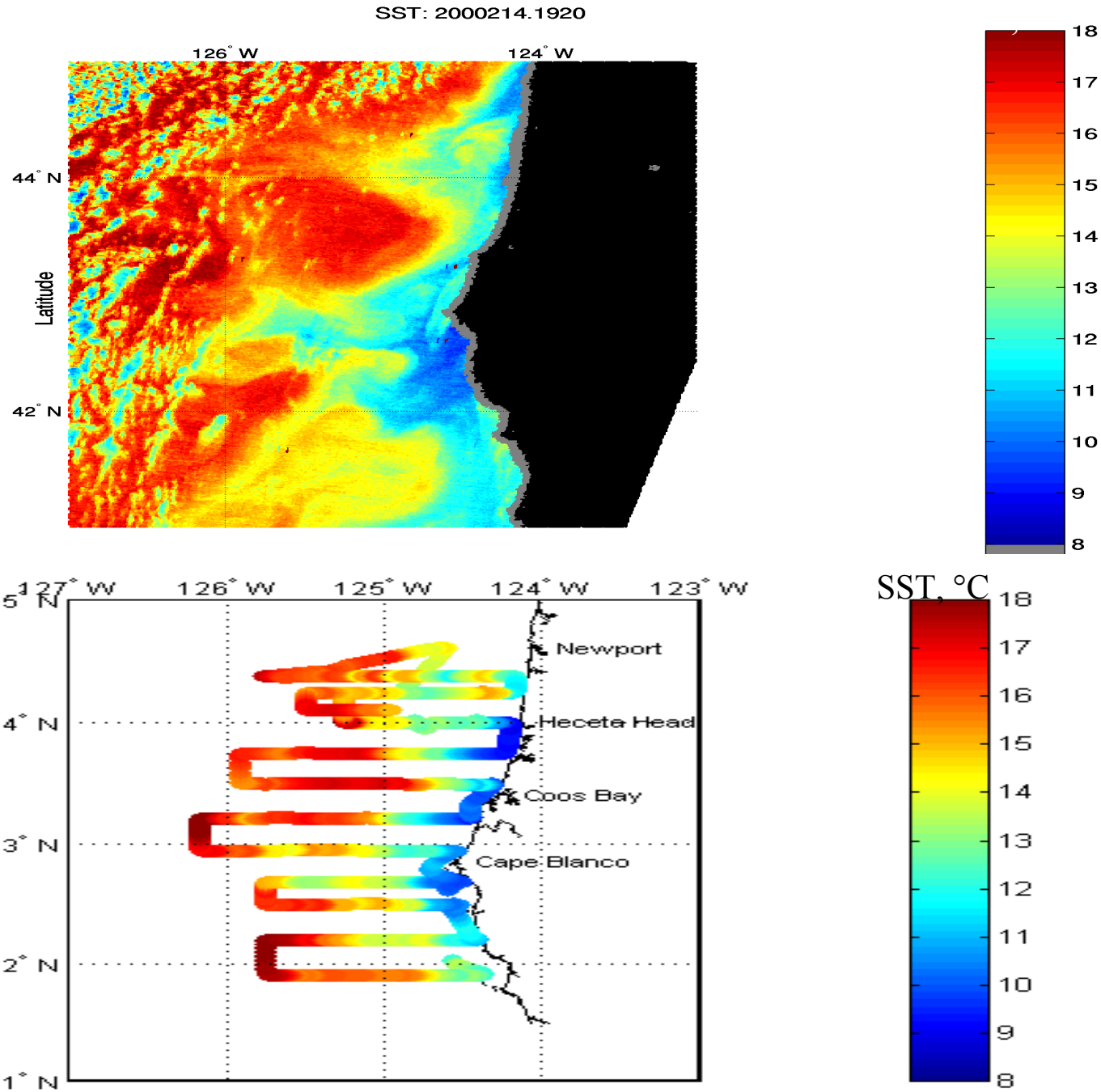
  a^* = chlorophyll specific absorption

  ϕ_F = fluorescence quantum yield

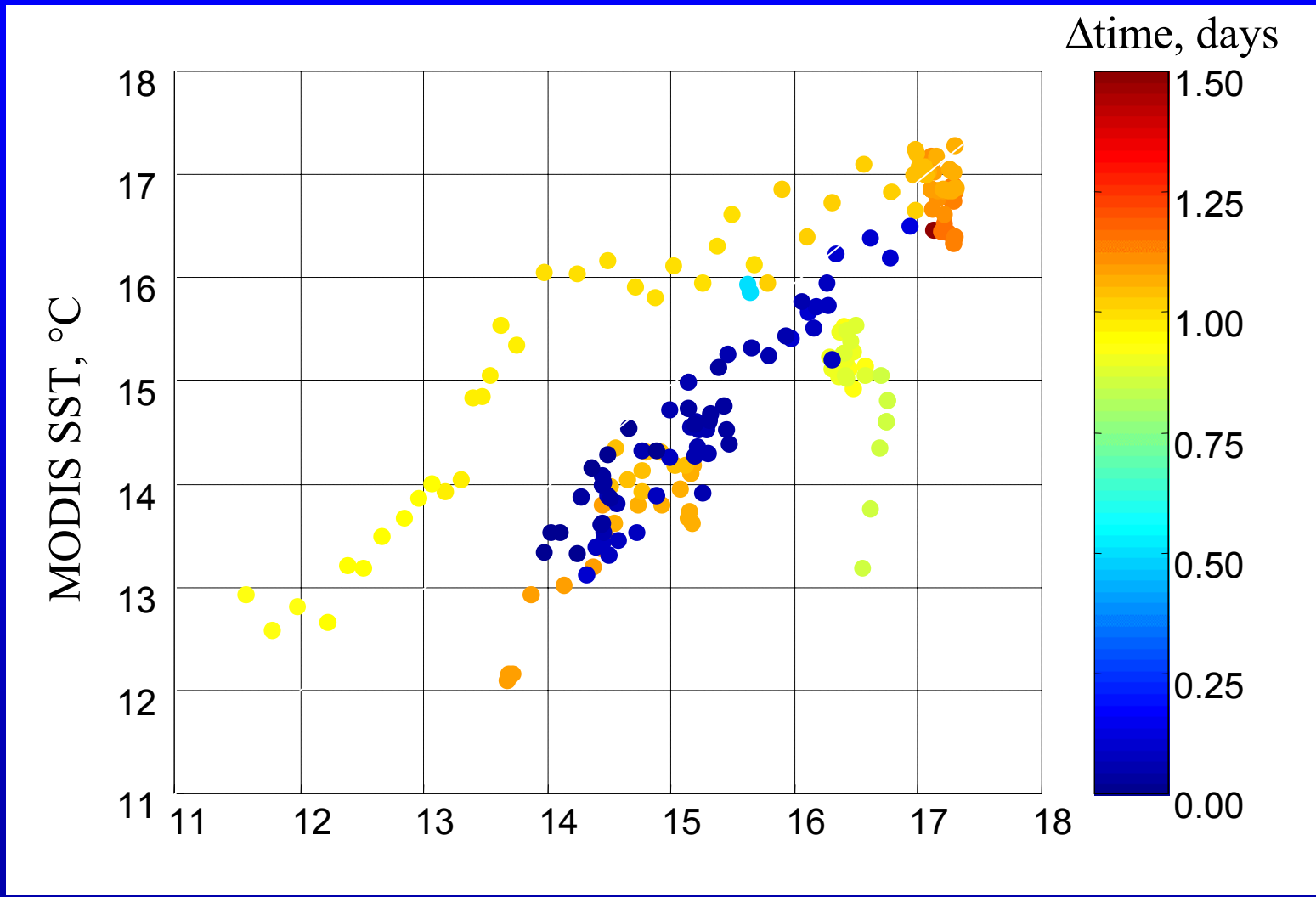
- We can rearrange as F/[chl] to estimate ϕ_F

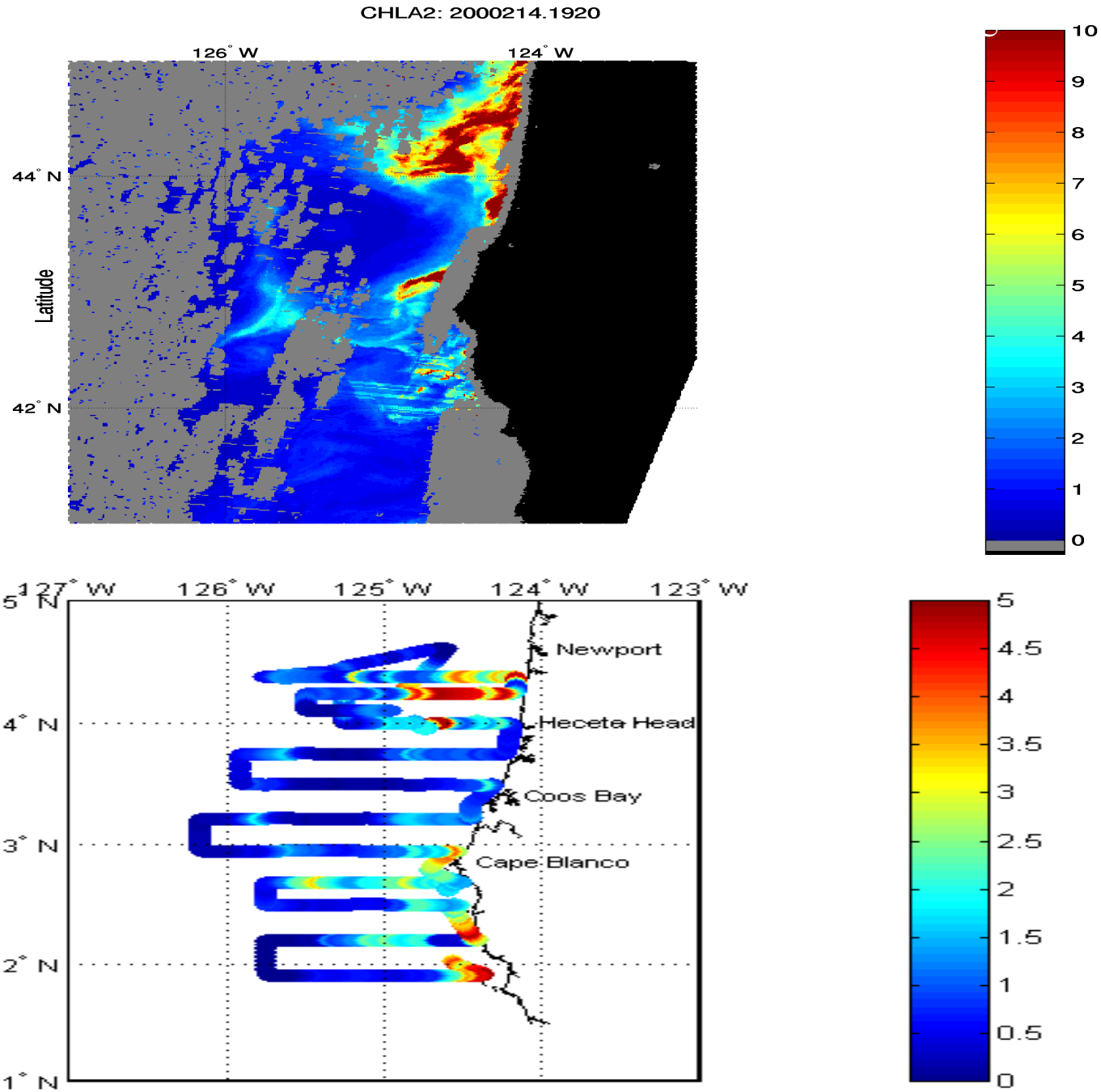
In Situ Observations of F/[chl]



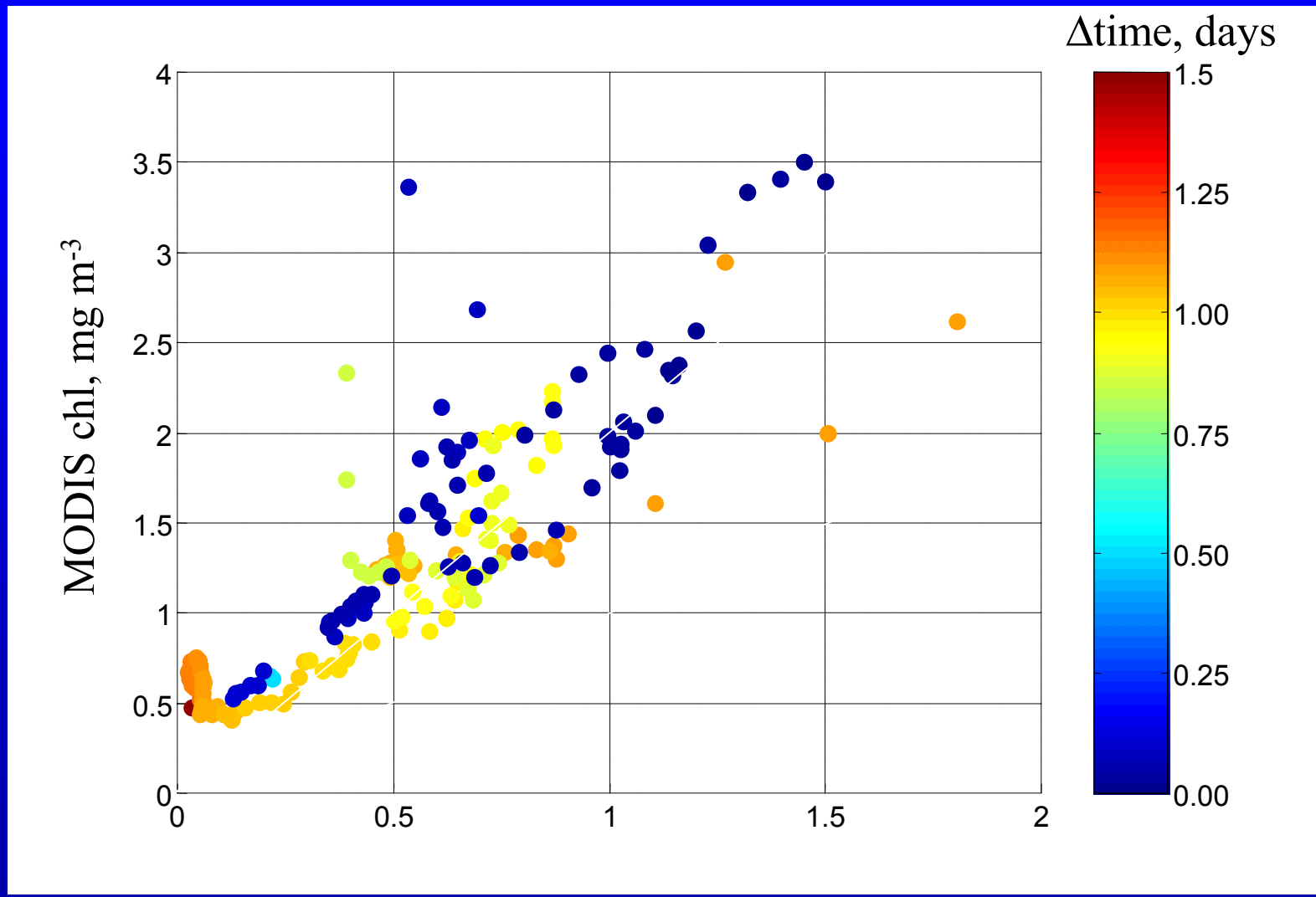

SST: 2000214.1920
126° W
124° W
44° N
42° N
Latitude
18
17
16
15
14
13
12
11
10
9
8
127° W
126° W
125° W
124° W
123° W
45° N
44° N
43° N
42° N
41° N
Newport
Hecete Head
Coos Bay
Cape Blanco
Latitude
Longitude
SST, °C
18
17
16
15
14
13
12
11
10
9
8

Comparison of Ship and MODIS SST

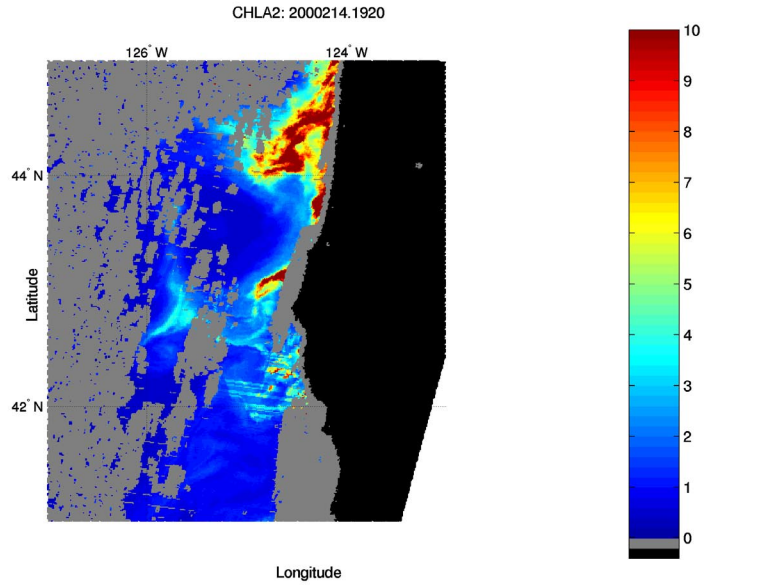



CHLA2: 2000214.1920
126° W
124° W
44° N
42° N
Latitude
10
9
8
7
6
5
4
3
2
1
0
127° W
126° W
125° W
124° W
123° W
45° N
44° N
43° N
42° N
41° N
Newport
Hecete Head
Coos Bay
Cape Blanco
Latitude
Longitude
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
mg m-3

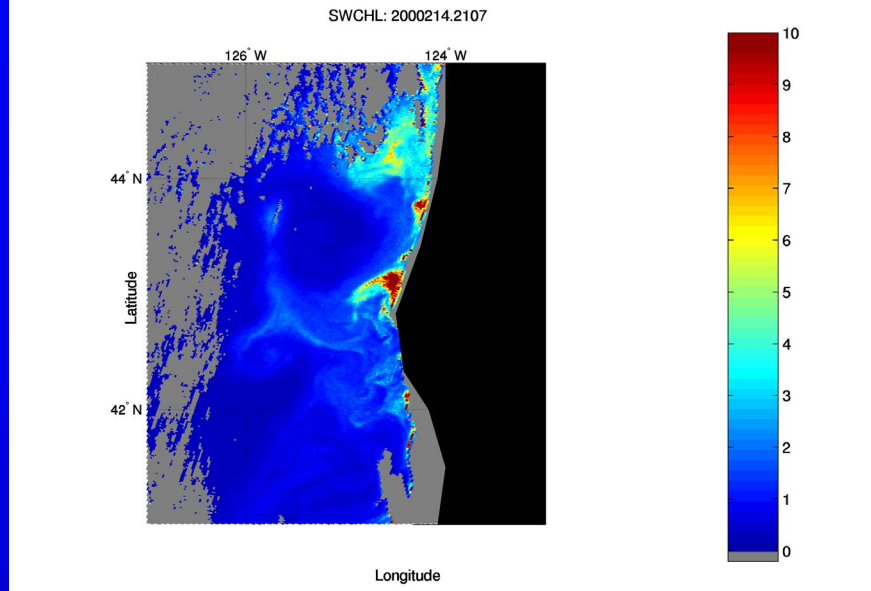
Comparison of Ship and MODIS Chlorophyll



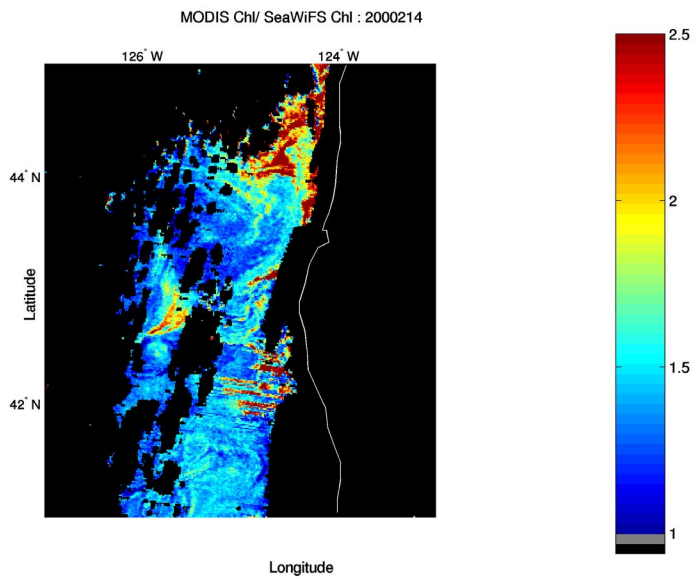
Chlorophyll Imagery from the Oregon Coast



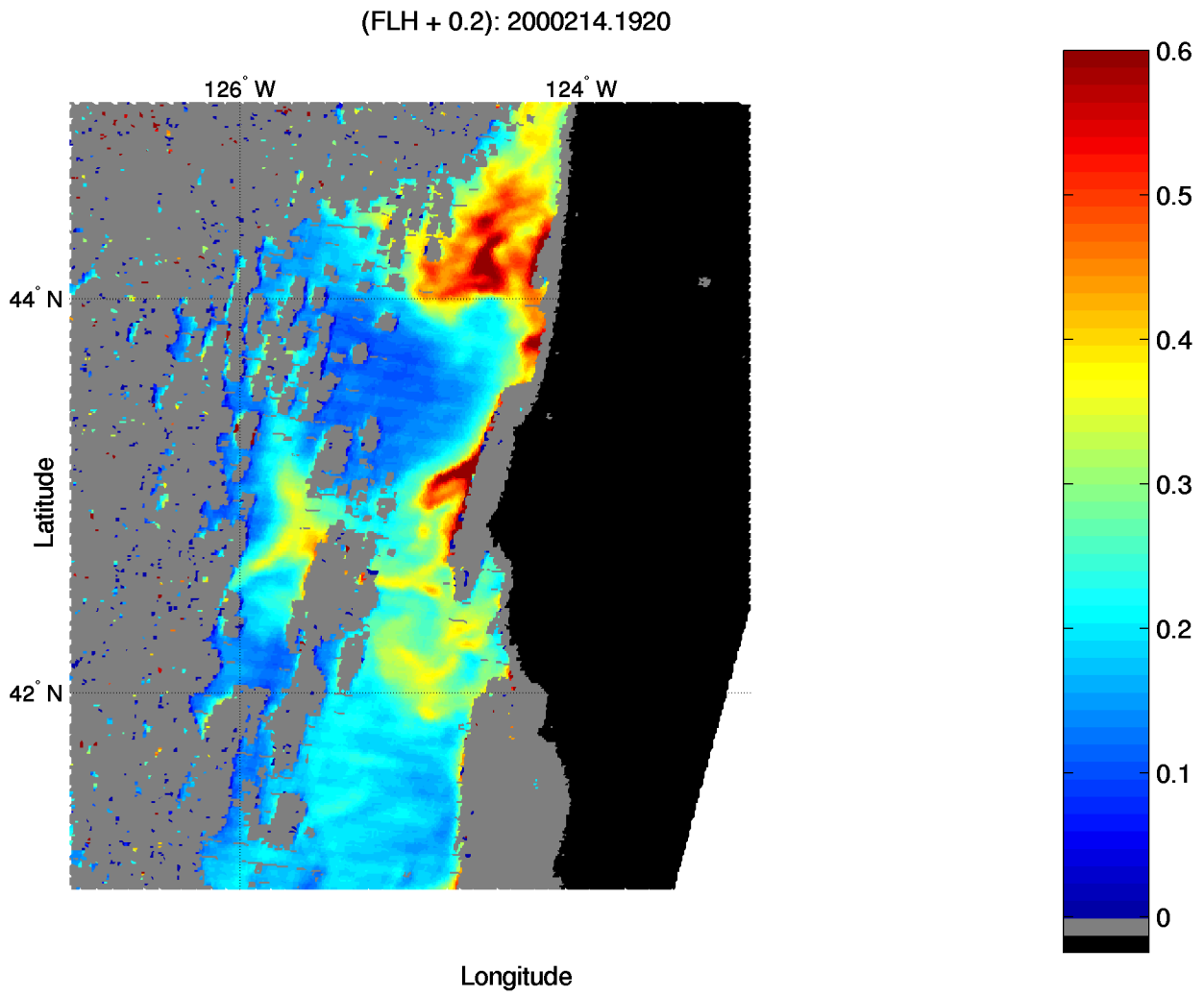
MODIS



SeaWiFS

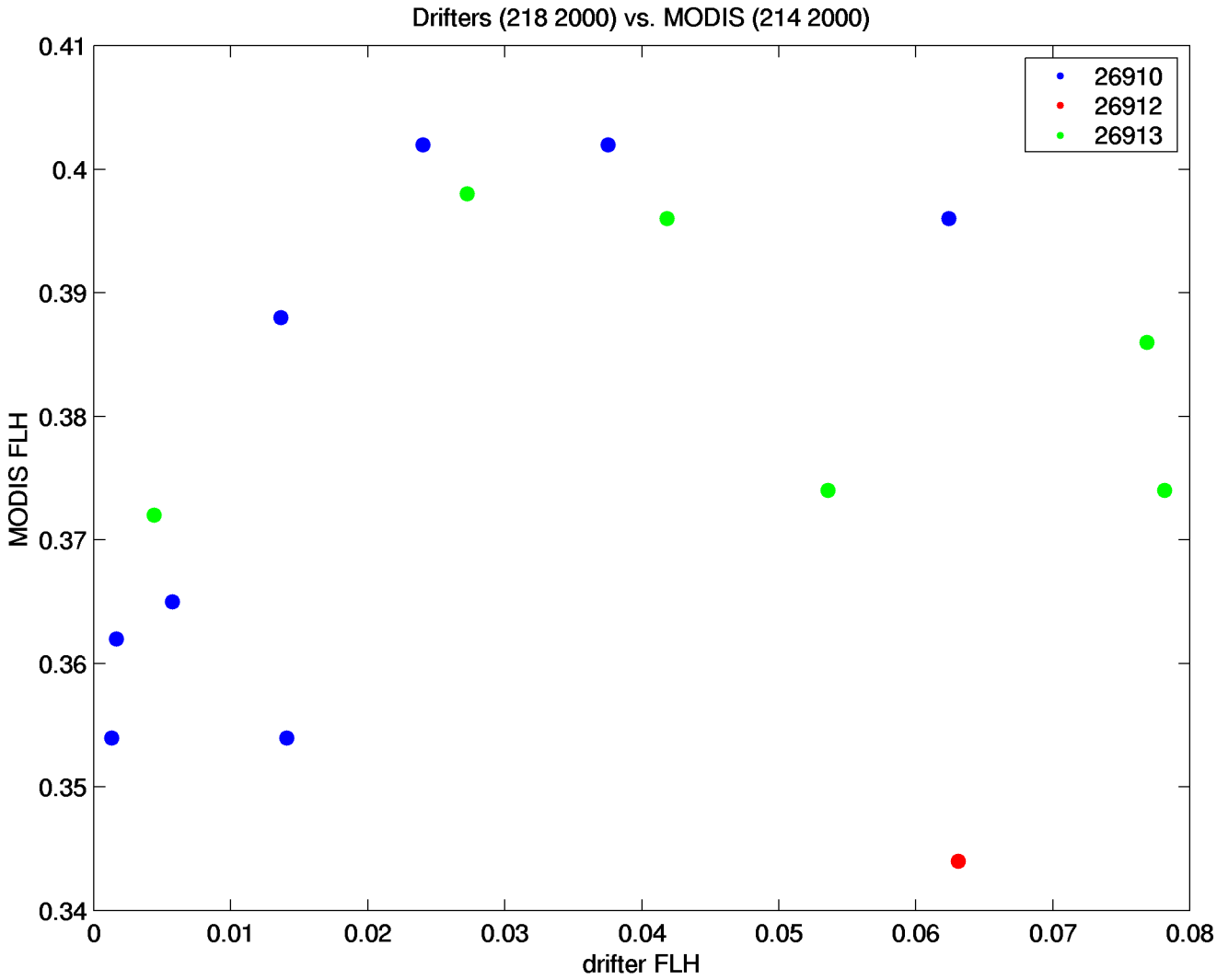


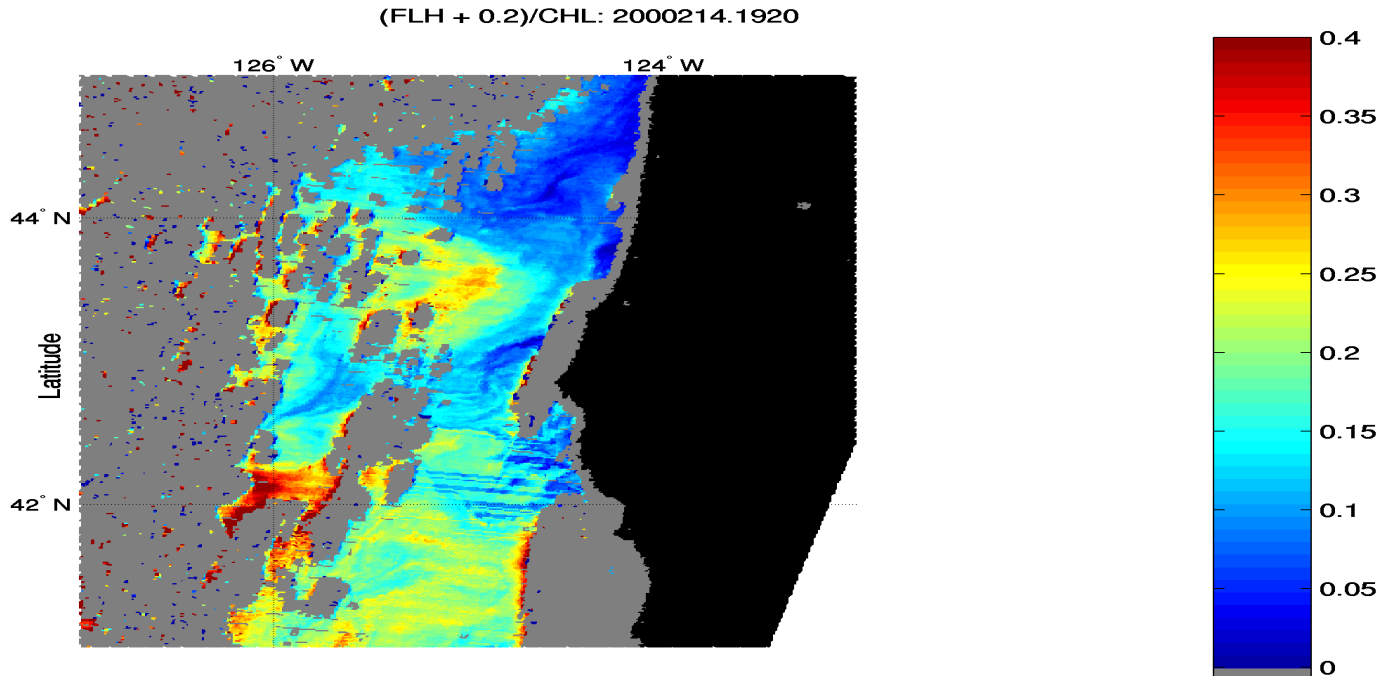
MODIS Fluorescence Observations

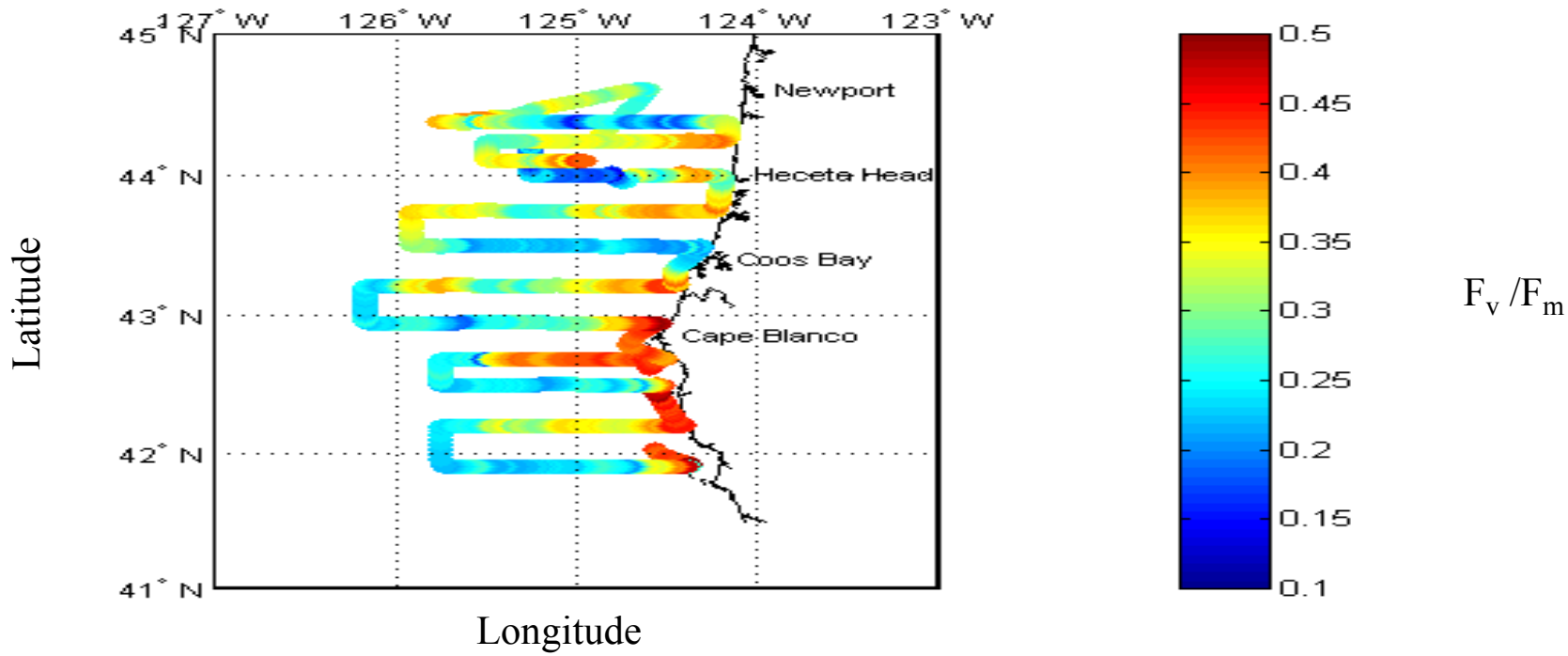


Fluorescence Line Height, baseline adjusted

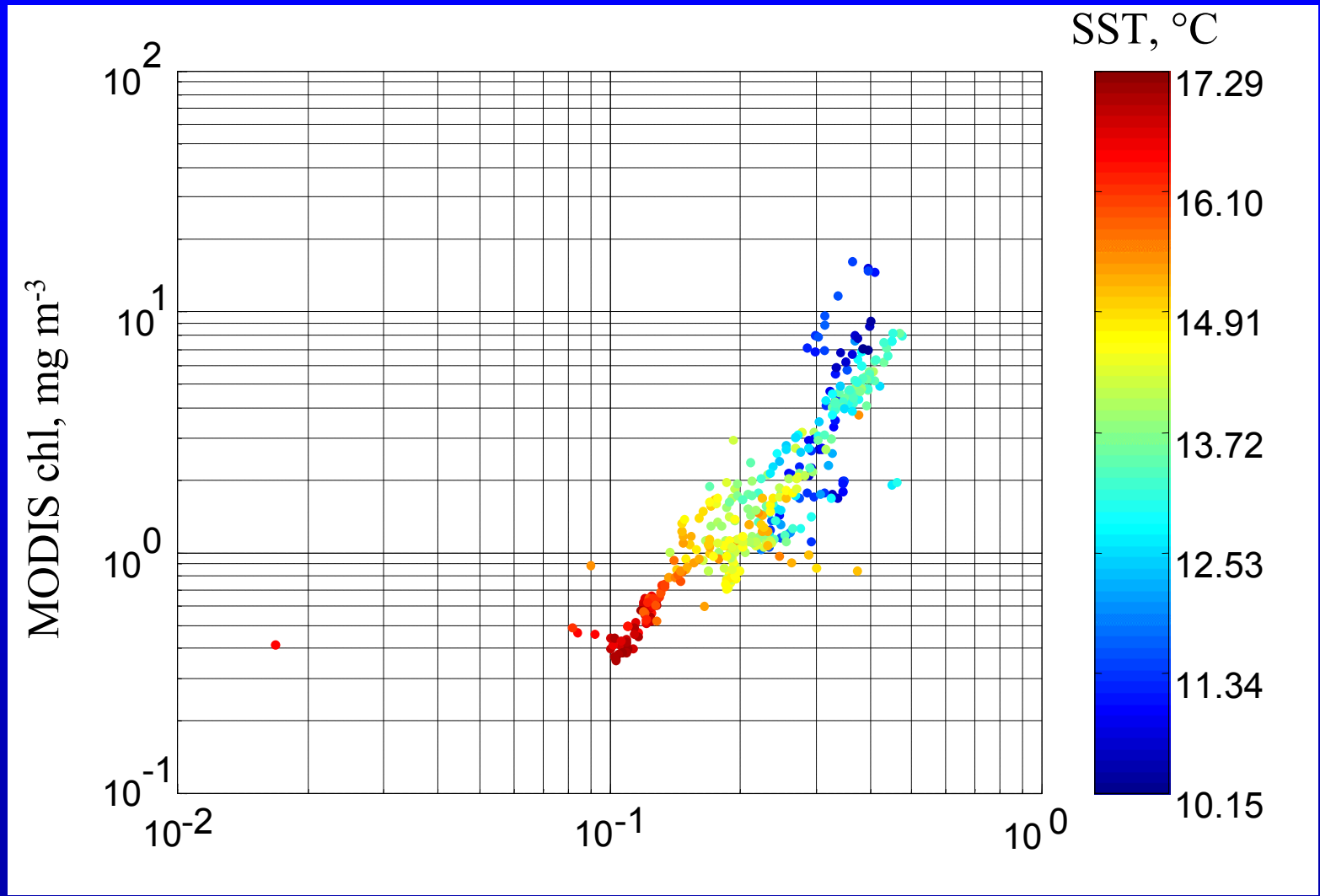
Drifters vs. MODIS Observations of FLH



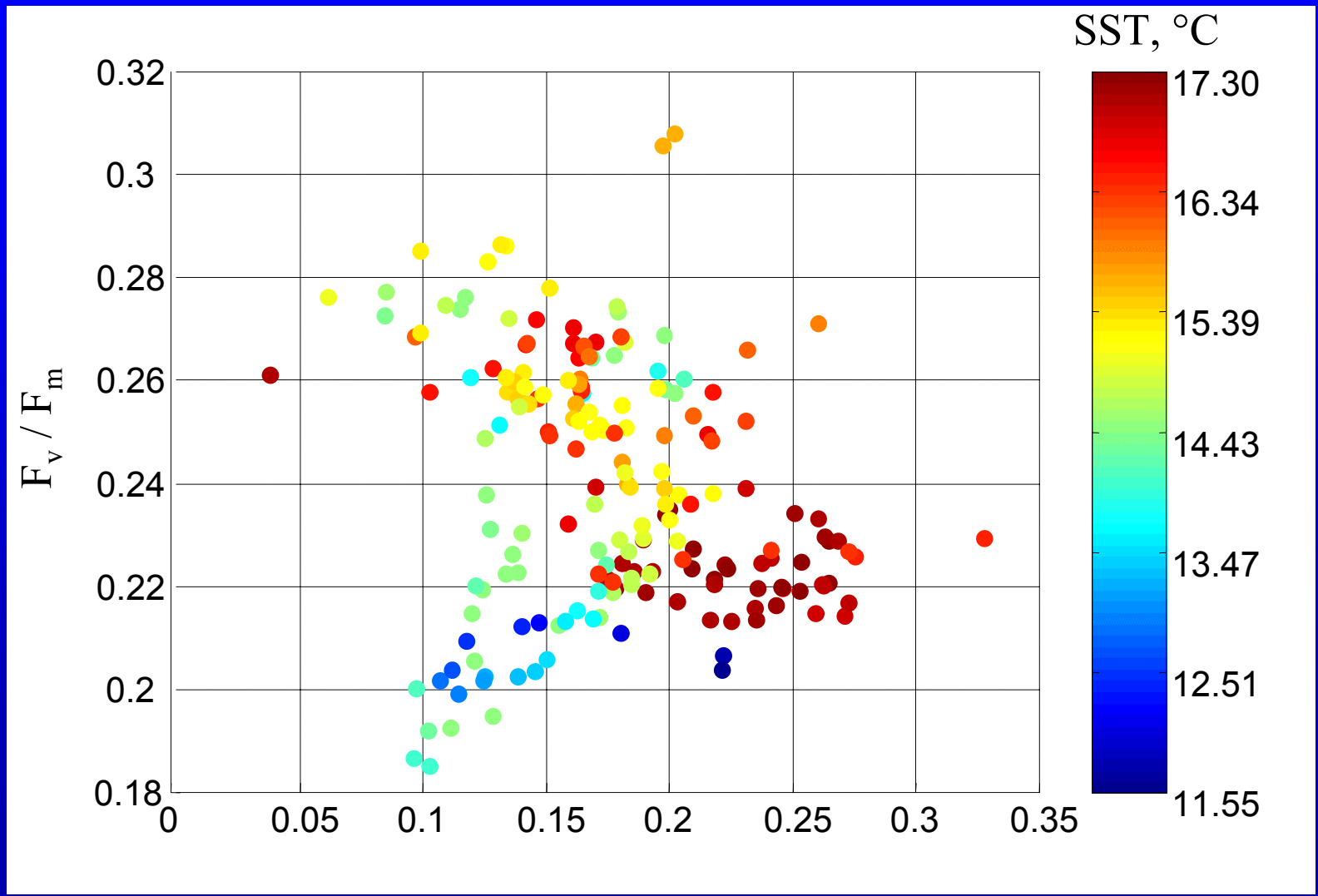

(FLH + 0.2)/CHL: 2000214.1920
126° W
124° W
44° N
42° N
Latitude
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0


127° W
126° W
125° W
124° W
123° W
45° N
44° N
43° N
42° N
41° N
Newport
Heceta Head
Coos Bay
Cape Blanco
Latitude
Longitude
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
F_v / F_m

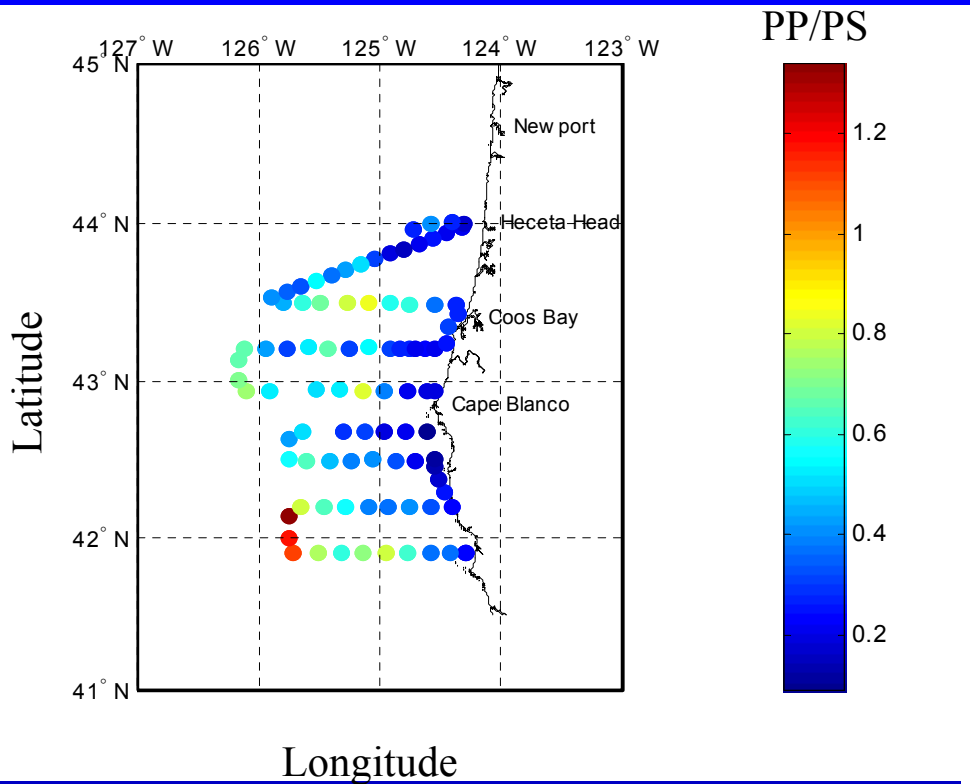
FLH vs. Chlorophyll as Function of SST



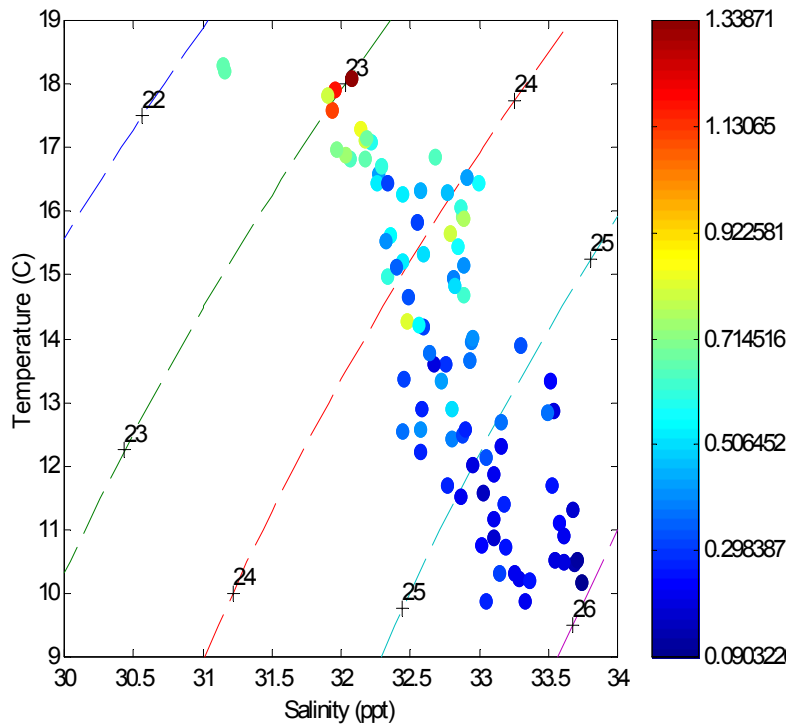
FLH/chl vs. F_v/F_m as Function of SST



Photosynthetic/Photoprotective Pigments



PP/PS



Key Points

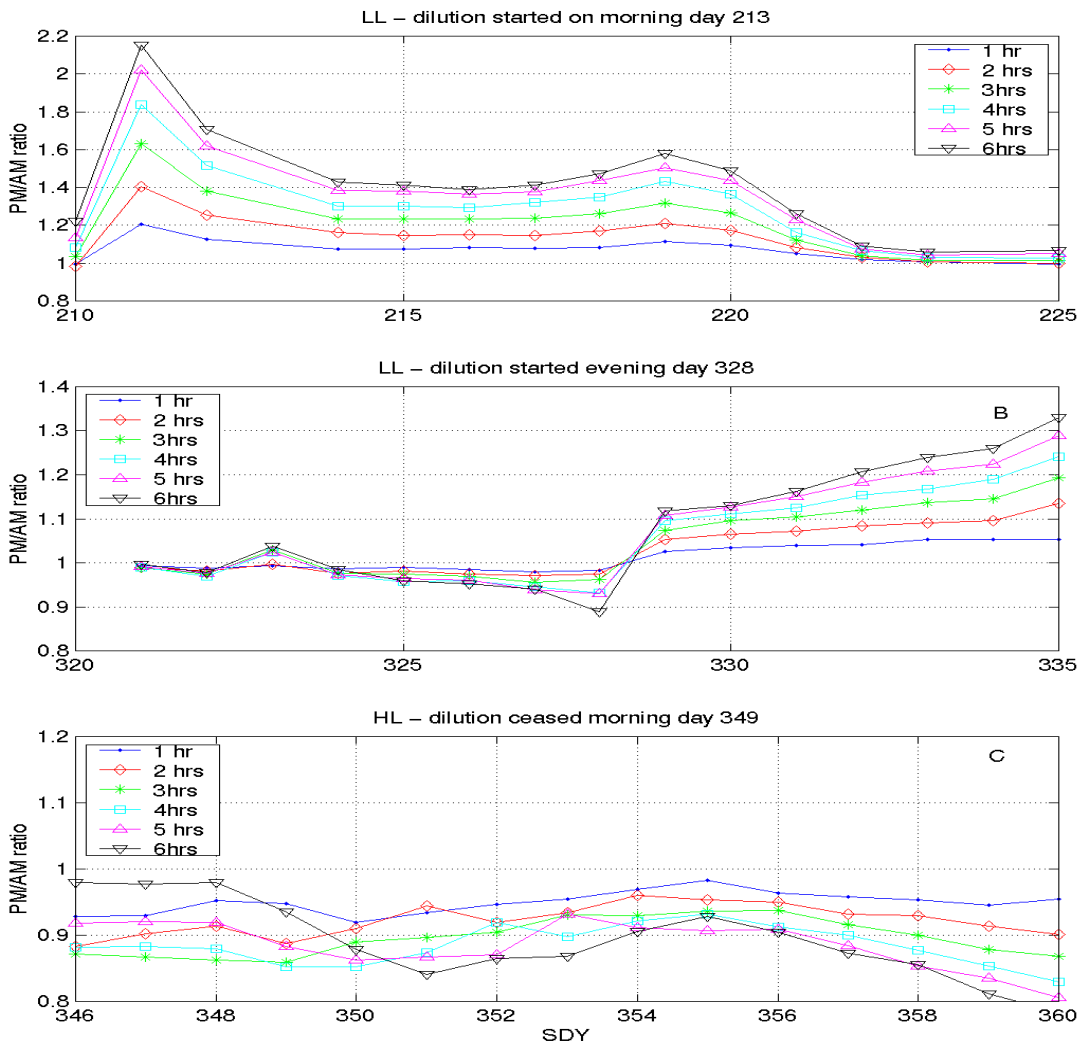
- General patterns of FLH/[chl]
  - Low FLH/[chl] in upwelling centers, Columbia River plume, high FLH/[chl] offshore
- General patterns of photosynthetic potential
  - High F_V/F_M in freshly upwelled waters, Columbia River plume, low F_V/F_M offshore
- But significant deviations from simple relationship between FLH/[chl] and F_v/F_m
  - Freshly upwelled waters, ratio of photoprotective pigments to photosynthetic pigments
- Quantifying these relationships and relating them to photosynthetic potential will require more work
  - Time history, regional dependence, etc.

Ratio of Morning/Afternoon ϕ_F

Nitrate starvation, low light

Nitrate addition, low light

Nitrate starvation, high light



How Can the Fluorescence Signal be Used?

- Field measurements show useful signal
- Chemostat studies of phytoplankton response
  - Can detect signal when shifting from nutrient-replete to nutrient-starved (and vice versa) under low-light conditions
  - Weak signal under high-light conditions
    - More complicated metrics do show signal
  - Much work remains for other species and other environmental conditions
- Challenge is to understand relationship between F/[chl] and photosynthetic potential
  - Time and space scales
  - Single measurements will likely not work

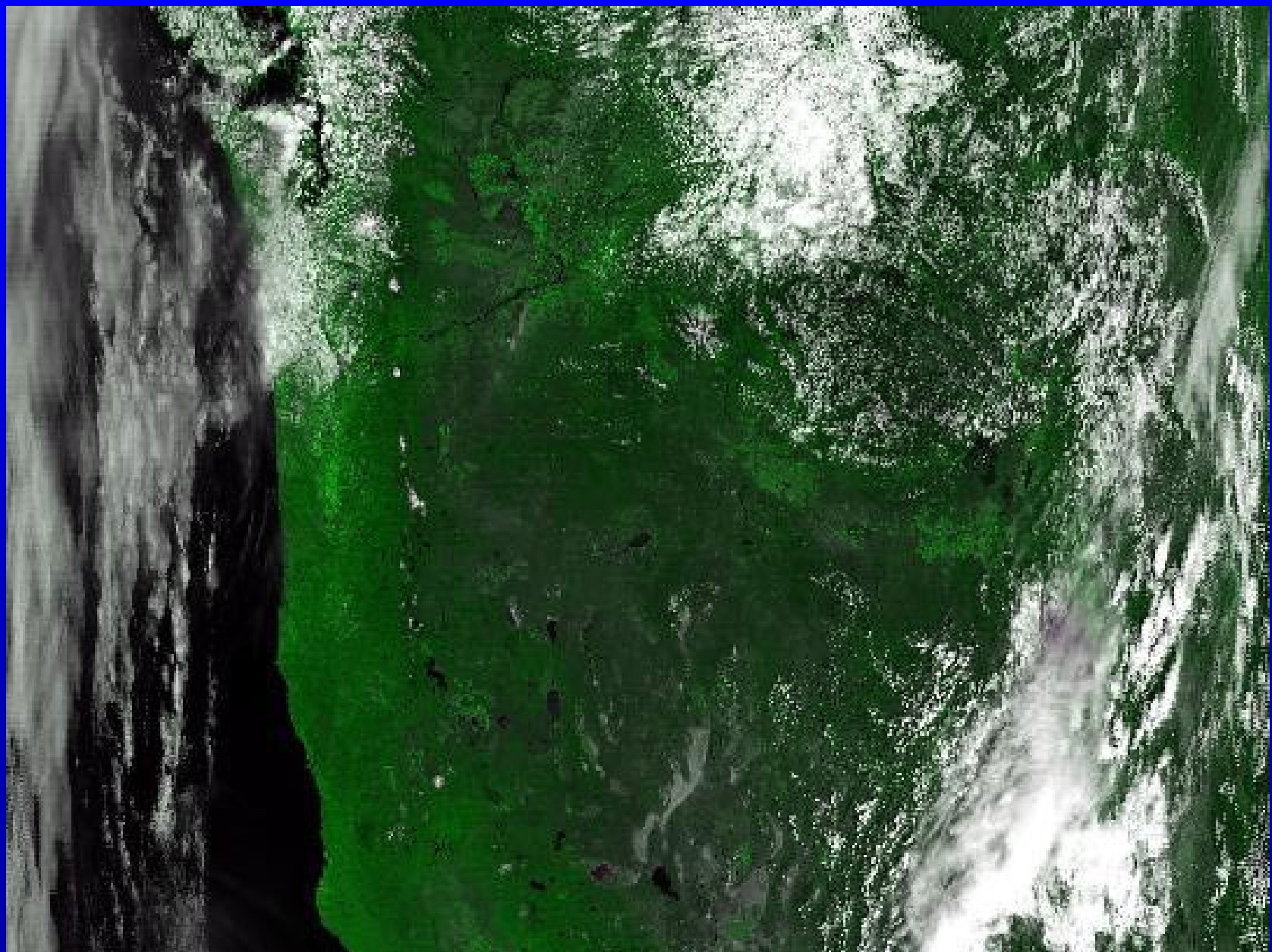
Conclusions

- Estimates of productivity on mesoscales essential for studies of ocean processes
- FLH can be detected from space, even at relatively low chlorophyll concentrations
- Variations in FLH/[chl] are related to changes in phytoplankton processes and photosynthetic potential
- Research required to turn qualitative relationships of FLH and productivity into quantitative models
- Launch of EOS-Aqua and other satellites (ENVISAT, ADEOS-2) will help

Acknowledgments

- Captain and crew of R/V Wecoma
- Jack Barth, chief scientist
- Chris Wingard, Rachel Sanders and Cidney Howard (OSU) for field sampling
- Bob Evans and Miami team for MODIS data
- SeaWiFS data from MBARI HRPT and processed by Ocean Optics group (R. Zaneveld, S. Pegau, OSU)

Real-time MODIS Data



550nm/470 nm MODIS 500m Resolution